

## CLAIMS

What is claimed is:

1. A variable-height thermal-interface device for transferring heat from a heat source to a heat sink, said device comprising:

a first uniaxial rotary cylindrical joint comprising a first cylindrically concave surface in slidable contact with a first cylindrically convex surface, said first cylindrically concave surface and said first cylindrically convex surface having a common first radius of curvature relative to a common first cylinder axis;

said first cylindrically concave surface operable to rotate about said common first cylinder axis relative to said first cylindrically convex surface to compensate for uniaxial angular misalignment between said heat source and said heat sink.

2. The device of claim 1 wherein:

said common first cylinder axis is inclined diagonally relative to the z-axis parallel to the shortest distance between said heat source and said heat sink; and

said first cylindrically concave surface is operable to slide linearly relative to said first cylindrically convex surface in a direction parallel to said common first cylinder axis to provide z-axis expansion of said variable height thermal interface device.

3. The device of claim 2 further comprising a spring clip mechanically spring loading said first cylindrically concave surface and said first cylindrically convex surface, said spring clip operable to apply a shear force across said first uniaxial rotary cylindrical joint, said shear force coupling to provide said z-axis expansion.

4. The device of claim 3 wherein said spring clip is shaped approximating a deformed rectangular frame, comprising:

a first side and a second side opposite said first side, wherein said first and second sides are bent inward toward one another;

said first side operable to couple a compressive force substantially parallel to said first cylindrically concave surface; and

said second side operable to couple an oppositely directed compressive force to said first cylindrically convex surface.

5. The device of claim 1, further comprising:

a second uniaxial rotary cylindrical joint comprising a second cylindrically concave surface in slidable contact with a second cylindrically convex surface, said second cylindrically concave surface and said second cylindrically convex surface having a common second radius of curvature relative to a common second cylinder axis;

said second cylindrically concave surface operable to rotate about said common second cylinder axis relative to said second cylindrically convex surface to compensate for uniaxial angular misalignment between said heat source and said heat sink.

6. The device of claim 5 wherein:

the orientation about said z-axis of said common first cylinder axis is different relative to the orientation of said common second cylinder axis about said z-axis; and

said first and said second uniaxial rotary cylindrical joints are operable to rotate cooperatively to compensate for biaxial angular misalignment between said heat source and said heat sink.

7. The device of claim 5 wherein:

said common first cylinder axis and said common second cylinder axis are each inclined diagonally relative to the z-axis parallel to the shortest distance between said heat source and said heat sink; and

said first and said second uniaxial rotary cylindrical joints are each operable to slide linearly to provide combined z-axis expansion of said variable height thermal interface device equivalent to the sum of the z-axis expansions of said individual first and second uniaxial rotary cylindrical joints.

8. The device of claim 1 further comprising a wedge interface having a first planar surface in slidable contact with a second planar surface, said slidably contacting planar surfaces inclined diagonally relative to the z-axis parallel to the shortest distance between said heat source and said heat sink, said wedge interface operable to provide z-axis expansion of said variable height thermal interface device.

9. The device of claim 1 further comprising a multi-axis rotary spherical joint operable to compensate for multi-axis angular misalignment between said heat source and said heat sink.

10. The device of claim 1 further comprising a shim operable to provide z-axis expansion of said variable height thermal interface device.
11. The device of claim 1 further comprising a conformal thermal-interface material applied to interface surfaces within said uniaxial rotary cylindrical joint.
12. The device of claim 1 wherein said uniaxial rotary cylindrical joint consists substantially of high thermal conductivity solid materials.
13. The device of claim 12 wherein said solid high thermal conductivity materials are selected from the group consisting of metals, insulators, semiconductors, and composite materials.
14. The device of claim 12 operable to transfer heat from said heat source through said uniaxial rotary cylindrical joint to said heat sink.
15. The device of claim 14 further operable to transfer heat under compressive loading applied between said heat sink and said heat source.
16. The device of claim 15 coupled mechanically and thermally with a heat sink hold-down device, wherein said heat sink hold-down device is operable to apply said compressive loading.
17. The device of claim 1 wherein said heat source comprises an integrated circuit chip.

18. A variable-height thermal-interface device for transferring heat from a heat source to a heat sink, said device comprising:

a first wedge interface having a first planar surface in slidable contact with a second planar surface, said slidably contacting first and second planar surfaces inclined diagonally relative to the z-axis parallel to the shortest distance between said heat source and said heat sink, said first wedge interface operable to provide z-axis expansion of said variable height thermal interface device; and

a second wedge interface having a third planar surface in slidable contact with a fourth planar surface, said slidably contacting third and fourth planar surfaces inclined diagonally relative to the z-axis parallel to the shortest distance between said heat source and said heat sink, said second wedge interface operable to provide z-axis expansion of said variable height thermal interface device.

19. The device of claim 18 wherein:

the orientation direction about said z-axis of said first wedge interface is different relative to the orientation direction of said second wedge axis about said z-axis; and

said first and said second wedge interfaces are operable to slide cooperatively to provide z-axis expansion of said variable height thermal interface device between said heat source and said heat sink equivalent to the sum of the individual z-axis expansions of said first wedge interface and said second wedge interface.

20. The device of claim 18 further comprising:

a spring clip mechanically spring loading said first wedge interface, said spring clip operable to apply a shear force across said first wedge interface, said shear force coupling to provide said z-axis expansion.

21. The device of claim 18 further comprising:

a first uniaxial rotary cylindrical joint comprising a first cylindrically concave surface in slidable contact with a first cylindrically convex surface, said first cylindrically concave surface and said first cylindrically convex surface having a common first radius of curvature relative to a common first cylinder axis;

said first cylindrically concave surface operable to rotate about said common first cylinder axis relative to said first cylindrically convex surface to compensate for uniaxial angular misalignment between said heat source and said heat sink.

22. The device of claim 18 further comprising a multi-axis rotary spherical joint operable to compensate for multi-axis angular misalignment between said heat source and said heat sink.

23. The device of claim 18 further comprising a shim operable to provide z-axis expansion of said variable height thermal interface device.

24. A method of transferring heat from a heat source to a heat sink using a variable-height thermal-interface device, said method comprising:

providing a first uniaxial rotary cylindrical joint comprising a first cylindrically concave surface in slidable contact with a first cylindrically convex surface, said first cylindrically convex surface and said first cylindrically concave surface having a common first radius of curvature relative to a common first cylinder axis;

sliding said first cylindrically concave surface relative to said first cylindrically convex surface, causing filling of gaps between said heat source and said heat sink;

applying compressive loading between said heat source and said heat sink through said first uniaxial rotary cylindrical joint; and

transferring heat from said heat source through said first uniaxial rotary cylindrical joint to said heat sink.

25. The method of claim 24 wherein said sliding comprises rotating said first cylindrically concave surface relative to said first cylindrically convex surface about said common first cylinder axis, causing compensating of uniaxial angular misalignment between said heat source and said heat sink.

26. The method of claim 24 wherein:

said common first cylinder axis is inclined diagonally relative to the z-axis parallel to the shortest distance between said heat source and said heat sink; and

said sliding comprises said first cylindrically concave surface sliding linearly relative to said first cylindrically convex surface in a direction parallel to said common first cylinder axis to provide z-axis expansion of said variable height thermal interface device.

27. The method of claim 26 further comprising:  
coupling a spring clip mechanically to said first uniaxial rotary cylindrical joint; and  
applying a shear force across said first uniaxial rotary cylindrical joint, causing a z-axis expansion of said first uniaxial rotary cylindrical joint.

28. The method of claim 25 further comprising:  
providing a second uniaxial rotary cylindrical joint comprising a second cylindrically concave surface in slidable contact with a second cylindrically convex surface, said second cylindrically concave surface and said second cylindrically convex surface having a common second radius of curvature relative to a common second cylinder axis;  
rotating said second cylindrically concave surface about said common second cylinder axis relative to said second cylindrically convex surface, causing compensating of uniaxial angular misalignment between said heat source and said heat sink;  
applying compressive loading between said heat source and said heat sink through said second uniaxial rotary cylindrical joint; and  
transferring heat from said heat source through said second uniaxial rotary cylindrical joint to said heat sink.

29. The method of claim 28 wherein:  
the orientation about said z-axis of said common first cylinder axis is different relative to the orientation of said common second cylinder axis about said z-axis; and  
said rotating of said first and said second uniaxial rotary cylindrical joints cooperatively compensate for biaxial angular misalignment between said heat source and said heat sink.

30. The method of claim 24 further comprising applying thermal-interface material to interfaces within said uniaxial rotary cylindrical joint.

31. The method of claim 24 wherein said applying compressive loading further comprises:  
providing a heat sink hold-down device operable to apply a compressive load;  
coupling said heat sink, said variable-height thermal-interface device, and said heat source mechanically and thermally with said heat sink hold-down device; and  
applying a compressive load between said heat sink and said heat source using said heat sink hold-down device.